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Battelle Technical Review

MOLYBENUM COORDINATOR

HARRY B. GOODWIN

"In these days, much of the security of our Nation may depend upon the speed of our jets. To increase that speed, we must find materials that will allow higher operating temperatures and thus give us the more efficient jet engines needed. Molybdenum, with a melting point about 2000 F higher than most metals, is the most promising high-temperature metal yet available". With this statement Harry B. Goodwin supplies the key to his work as Battelle's coordinator of molybdenum studies being conducted under the sponsorship of the Office of Naval Research.

Harry came to the Institute in 1949 from the Applied Physics Laboratory at Silver Springs, Maryland. His work there was on metallurgical problems related to the development of ram-jets. In that connection, he helped to plan and organize the molybdenum research program. At Battelle, in addition to his activity as coordinator of ONR molybdenum research, Harry assists in Air Force and AEC-sponsored investigations in the same field.

Recently, he became secretary of the Advisory Committee on Molybdenum of the Office of Naval Research. The committee gives much attention to ONR activities in its field, advises on the molybdenum research of other government agencies, and serves as a clearing house of information for private organizations.

A five-and-a-half year tour of military duty preceded Harry's work in the field of molybdenum. After receiving his bachelor of science degree in metallurgy from the Massachusetts Institute of Technology in 1937, he was associated first with the Bethlehem Steel Company and then with the Crown Cork and Seal Company. As research metallurgist for the latter, he assisted in developing a continuous annealing furnace for sheet steel, and other steel-working processes.

Much of Harry's free time is taken by his daughter and two sons. However, he does indulge in his hobby of photography and has hopes of doing some sailing again soon.

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Technology and Employment

Approximately 62 million people in this country are now gainfully employed. There is virtually no reservoir of unemployed labor, and nearly every skill, trade, or profession is in demand. Many workers, because of the need for their abilities, hold more than one job. Housewives, men of retirable age, persons of independent income, and others not driven by economic necessity are numbered among the labor force.

This is the employment picture in the United States in 1953. More work is waiting to be done than there are people to do it. And yet for a century or more we in this country have bent every effort to devise machines to save labor—to replace manpower. Also, like no other nation, we have been successful in creating mechanical servants to do our work. How can such a paradox exist?

War and threats of war, some people would say, explain our high employment. War does cause surges in economic activity, but it can not account for 62 million jobs. The real explanation lies in the fact that machines and labor-saving devices do not put men out of work. They may cause temporary dislocations, but invariably they create more jobs than they render obsolete. By expanding the areas and horizons for human endeavor, they increase the need for workers. When technology took the scythe from the field hand, it did more than put him on a combine. It put his brother in a farm machinery factory, his sister in a wheat brokerage office, and his father in a grain elevator.

The National Academy of Sciences and the National Research Council, as well as others, have estimated that fifty per cent of the Nation's workers today are employed in industries that did not exist in 1880. Since practically all of the new industries developed since 1880 have been based on technology, this means that nearly 31 million people are working at jobs that were created directly by technology. It does not mean that 31 million people would now be unemployed had there been no technical progress, but rather that the natures of their present occupations have been established directly by this progress. Had it not been for the vigor and daring of our people, acting on all fronts of our economy to bring about better things through the application of science and invention, much of our population would now be engaged in subsistence-level pursuits.

Many people not working in technologically created industries also owe their livelihoods indirectly to technical advances. A new plastics industry, an aeroplane factory, or a refrigerator plant helps the miner, the baker, the lumberman, and the grocer's clerk only slightly less than it helps its own employees.

In creating jobs for workers, technology always moves in one direction—to upgrade those it benefits. It makes the individual more productive and thus of more value to society. Thus his earnings increase. At the same time, the cost in man-hours of products the worker buys are lowered. As a result, men, in only moderate circumstances by today's comparison, achieve luxuries beyond those of former kings. Thus, technology by freeing man from the gaunt struggle to keep alive gives him opportunity for social and cultural development and the realization of personal dignity.

Clyde Williams

Director, Battelle Memorial Institute

Multi-Curie Radiation Sources in Industry

by RALPH BELCHER

The author directs radiochemical research at Battelle. Before joining the Institute in 1948, he was associated with the Hanford Engineering Works, at Hanford, and with the Tennessee Eastman Corporation and the Monsanto Chemical Company at Oak Ridge. Most of his research activity has been in connection with Atomic Energy Commission-sponsored projects.

IN 1895 WILHELM VON ROENTGEN, like many other physicists of his time, was investigating the cathode rays emitted from a highly evacuated discharge tube. He was particularly interested in the fluorescence of the glass walls of the tube. During one experiment he was surprised to find that some barium platinocynide crystals fluoresced brightly even when the discharge tube was completely covered with a light-tight cover. Also, he found that any object placed between the discharge tube and a fluorescent screen would cast a shadow on the screen. Roentgen concluded that the tube must be discharging unknown rays, invisible to the human eye, but able to penetrate solid objects. He called these emissions X-rays.

About the same time, Henri Becquerel also became interested in this phenomenon. He successfully prepared potassium uranyl sulfate and observed its intense phosphorescence under ultraviolet light. Consequently, in 1895 and 1896, when scientists were searching for the relationship between X-rays and phosphorescence, it was natural for Becquerel to enter actively into this study.

Becquerel found that uranium sulfate, after being exposed to sunlight of any intensity, would blacken a photographic plate even when the plate was covered by black paper. He also found that other crystals of uranium salts would darken photographic plates even without previous exposure to sunlight. It was the Curies who concluded that the rays were atomic in nature and characteristic of the element uranium. The Curies gave the name "radioactivity" to this phenomenon. Today we know that the emissions from uranyl salts are alpha particles, beta particles, and gamma rays.

The early scientists soon realized that radioactive materials contained a significant store of energy. As early as October, 1903, the *St. Louis Post-Dispatch* carried an article speculating on this inconceivable new power and its use in war as an instrument of destruction. However, until the advent of the nuclear pile, the supply of radioactive elements and their isotopes, now known generally as radioisotopes, was limited. They were few in number and difficult to procure since radioisotopes are rare in nature. Up to 1940 only about 1000 grams of radium (most useful of the early isotopes) had been isolated and the cost rose to as high at $135,000 per gram. For these reasons, radioisotopes were primarily employed in laboratory experimentation, medical therapy, radiographic inspection, and for the preparation of luminescent paints for radium dials.

During the summer of 1946, the Atomic Energy Commission made reactor-created radioisotopes available to qualified users for the first time. Since then, over 40,000 shipments of over 100 different radioistopes have been made. Roughly 22 per cent of these shipments have gone to industry and about 3 per cent to nonprofit and private organizations. Most radioisotopes can now be obtained at a cost of several dollars or less per millicurie, the quantity of a radioisotope that emits 3.7×10^7 disintegration particles per second.

Since 1944, when the first nuclear reactor went into operation, billions of curies of radioisotopes have accumulated as a by-product of plutonium production. Accumulation will continue unless more applications for radioisotopes can be found. Several uses that have been proposed and that are being investigated include radiographic inspection, sterilization, and radiation chemistry. Of these, radiation chemistry appears most promising.

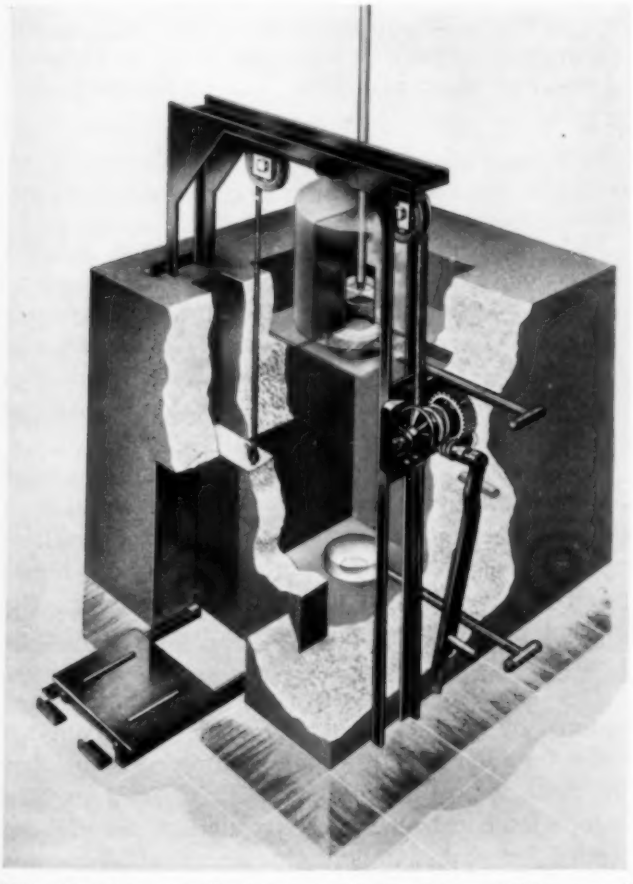
RADIATION CHEMISTRY

The most familiar of the applications of radioisotopes as tracers is in following the course of chemical reactions, the movement of oil through pipe lines, the assimilation of food by plants, and the many uses in the field of medicine. But the use of radioisotopes in radiation chemistry is seldom mentioned. Radiation

chemistry is concerned with the chemical effects of all ionizing radiation including high-energy particles. The particles and rays discussed in this paper have been limited to the alpha particle, beta particle, and gamma ray.

The characteristics of each of these types of emission help to determine its function. Alpha particles are the nuclei of helium atoms that have lost their two planetary electrons and are positively charged. The range of the alpha particle in air is only a few centimeters and it can be stopped by a sheet of paper. Beta particles are negatively charged particles, or electrons, ejected from the nuclei of atoms at high velocity. They are much more penetrating than alpha particles and the more energetic ones can penetrate several millimeters of metal. Gamma rays are a form of electromagnetic radiation of nuclear origin with a very short wavelength and with penetrating power comparable to X-rays.

These particles and rays all have the ability to alter the electronic structure of a target atom upon collision. When the target atom loses an electron as a result of the collision, the atom becomes electrically unstable and is known as an ion. A measure of the efficiency of these radiations in producing changes in target materials is indicated by their specific ionization. The specific ionization, that is, the number of ions produced per unit length of path, increases in the following order: a gamma ray may produce 1.5, a beta particle 50 to 100, and an alpha particle 20,000 to 40,000 ion pairs per centimeter of air.



This Battelle installation was designed to hold several hundred curies of cobalt-60. The lead housing weighs approximately 300 pounds and provides 10 inches of lead shielding. The unit can be used for sample irradiation or for radiographic inspection. A cross-sectional view of the unit is shown.

Until 1946, the study of the effects of radiation on matter was limited almost entirely to laboratory experimentation and the college classroom. With millions of curies of radioisotopes now potentially available, the many industrial aspects of radiation chemistry are being investigated with vigor by industrial and research laboratories.

Problems that are receiving particular attention are:

1. Initiation of chemical reactions.
2. Production of self-luminescent phosphors.
3. Degradation and radiolysis of materials.
4. Destruction of microorganisms.

Initiation of Chemical Reactions

Alpha, beta, and gamma radiations lose energy by interaction with matter. The energy absorbed produces ionization, free radicals, and excited molecular states in the matter. Under certain conditions these excited parts may recombine to form new products. In reactions where excited molecular states, ions, or free radicals are required to form a product, an uneconomic amount (at the present time) of radiation is usually required. For example, it has been calculated that at least one billion roentgens would be required to break one per cent of the bonds in one gram of a typical hydrocarbon.* Yet the radiation from one hundred curies of cobalt-60, a few inches from the source, is only of the order of 125,000 roentgens per hour. It is therefore obvious that an astronomical number of curies of cobalt-60 would be required to carry out such a reaction as the commercial cracking of petroleum. However, when an excited particle can "trigger" a chain reaction, the use of radiation as an initiator appears promising. Many reactions of this type are known. Gamma radiation has been used to polymerize such monomers as butadiene, styrene, acrylonitrile, methyl methacrylate, and vinyl acetate. Radiation has also been used to initiate halogenation reactions such as the chlorination of benzene.

It can be stated, as a general rule, that reactions catalyzed by ultraviolet radiation can also be catalyzed by alpha, beta, or gamma radiation. In cases where

*Reported in *Industrial Engineering Chemistry*, June, 1952, p. 11a.

materials are inflammable, the use of high voltage to produce ultraviolet radiation can constitute a fire hazard. The use of nuclear radiation eliminates this danger.

Experiments have been conducted in combustion engines whereby the fuel is subjected to intense radiation with the hope of better engine performance.

Production of Self-Luminescent Phosphors

Radium has long been used in the preparation of luminescent paint for dials. The radiation from the radium stimulates the phosphor and makes the figures on the dial visible in the dark. Radium, however, has the disadvantages of emitting penetrating gamma rays and also of decaying into radon, a very dangerous radioactive gas. Now, several radioisotopes which emit only weakly penetrating beta radiation are available. As a result, the production of beta-stimulated phosphors is being studied. Standard light sources prepared from materials such as zinc sulphide and stimulated by strontium-90 can be obtained from commercial distributors. Tritiated stilbene, which contains radioactive hydrogen, has also been made available. It can also be used as a low-intensity light source in the ultraviolet region.

Radiolysis of Materials

Radiolysis or study of the breakdown of materials under ionizing radiation is of particular concern to the nuclear engineer. How does radiation affect the life of a lubricant used in an engine subjected to intense radiation? Do the metals used in the engine become brittle after prolonged irradiation? Does paint covering parts of the engine become blistered? If so, why?

COMMON RADIOISOTOPES OBTAINED AS BY-PRODUCTS FROM PRODUCTION OF PLUTONIUM

Isotope	Half-Life	Beta Energy, MEV	Gamma Energy, MEV
Strontium-90	25 years	0.61	None
Yttrium-90*	62 hours	2.3	None
Technetium-99	1×10^6 years	0.03	None
Ruthenium-106	1 year		None
Rhodium-106*	30 seconds	3.5 (82%)**	0.51 (17%)**
		2.3 (18%)	0.73 (17%)
			1.2 (1%)
Cesium-137	33 years	0.5 (95%)	None
		1.19 (5%)	
Barium-137*	2.5 minutes	None	0.66
Cerium-144	290 days	0.35	None
Praseodymium-144*	17.5 minutes	3.0	0.2
			1.2
Promethium-147	4.4 years	0.22	None

*Radioactive daughter of strontium-90.
**Figures in parentheses show relative intensities.

IMPORTANT RADIOISOTOPES PRODUCED IN A REACTOR

Isotope	Half-Life	Beta Energy, MEV	Gamma Energy, MEV
Hydrogen-3	12.5 years	0.0189	None
Carbon-14	5740 years	0.154	None
Phosphorus-32	14.3 days	1.712	None
Sulfur-35	87.1 days	0.167	None
Cobalt-60	5.2 years	0.31	1.17
			1.33
Tantalum-182	117 days	0.25	33 gammas
		0.53	0.046 1.237
Thallium-204	2.7 years	0.783	None
Iridium-192	70 days	0.67	12 gammas
			None
Palladium-109	13.1 hours	0.95	0.137 0.651

And how can these breakdowns be prevented? These are some of the questions being asked and some of the problems being investigated in this field. The answers to the questions and the solutions to the problems will permit the construction of better nuclear reactors and will hasten the day of extended use of nuclear power for industrial purposes. Meanwhile, in the realm of pure science, the physicists are investigating the radiolysis of organic compounds such as benzene, toluene, and others in order to discover the mechanism by which radiation decomposes matter.

Destruction of Microorganisms

The effects of radiation upon biological material offers another fertile field for investigation. Of particular interest is the possibility of controlling organisms in food by sterilization and pasteurization by this method. The advantage of radiation is that there is no appreciable temperature rise in the material, since the organisms are killed by ionization.

Radiation has been found to affect organisms in at least two ways. Under certain conditions, irradiation of biological material will produce mutations. These mutations may prevent the reproduction of organisms, thereby preventing an increase in their count. Organisms may also be destroyed outright by massive doses of radiation.

The amount of radiation required for sterilization of material by an isotope such as cobalt-60 is about 100 curies for each pound of material processed per day. On the other hand, only about 20 curies of such an isotope for one hour for each pound of material are needed for pasteurization. One can readily see that many millions of curies of radioisotopes would be required for commercial operations of this nature.

Already much work has been done on the sterilization and pasteurization by radiation of foods and

medicines. Of particular interest is the work being carried on at the University of Michigan. It has been reported that hermetically sealed meats have been kept fresh for over a year without refrigeration, by subjecting the meat to radiation. Despite the progress made thus far, however, it will probably be several years before engineering techniques can be perfected to a point where commercial installations will become economically feasible. The encapsulation of millions of curies of beta-emitting isotopes so that they can be utilized safely is only one of the problems yet to be solved. This and other problems will undoubtedly be worked out as the economic advantages of sterilization are recognized.

Radiation Sources

Radiation sources can be classified according to their method of production as well as the kind of radiation they emit. Radioisotopes are produced from the fission of uranium-235 (fission products) during the production of plutonium and also by subjecting a material to bombardment by such sources of neutrons as are available in a nuclear reactor. There are some useful radioisotopes that cannot be produced satisfactorily in a nuclear reactor or obtained from fission products, but which can be prepared with such high-speed accelerators as a cyclotron. Some of the radioisotopes produced in cyclotrons are beryllium-7, manganese-54, sodium-22, and zinc-65 free of zinc-69.

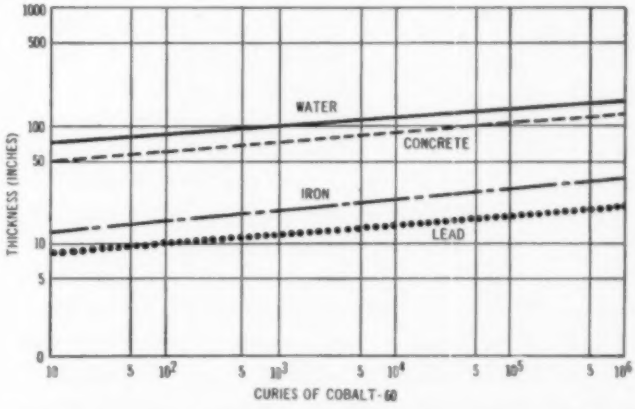
Pile-produced radioisotopes are prepared by bombarding nonradioactive isotopes with neutrons. During this process, some of the atoms will absorb neutrons and become radioactive. No matter how long a material is irradiated, the final product will not have all of its atoms radioactive because of the decay that starts in as soon as they are formed. Thus a pile-irradiated sample, though it is highly radioactive, will contain relatively few radioactive atoms compared with the total number of atoms present.

On the other hand, when uranium-235 splits into fragments (fission) during the production of plutonium, a large number of radioisotopes (fission products) are formed. These radioisotopes have all of their atoms radioactive at the time of formation. Thus, an extremely high concentration of radioactivity can be obtained per unit mass of a fission product. This characteristic of fission products makes them ideally suited for radiographic work where a small, intense source of radiation is often needed.

Thus far, most irradiation studies on a large scale have utilized cobalt-60. This isotope has several advantages over other radioisotopes. It can be obtained in very large quantities at low cost, and it has a high specific activity (ratio of the number of radioactive atoms to the total number of atoms of the element in the sample). However, cobalt-60 emits two very penetrating gamma rays that require 6 feet of concrete or 10 inches of lead to protect workers from the radiation of 100 curies. In many cases cobalt-60 is being used where the less penetrating beta radiation would be more efficient and less hazardous. However, at the present time, multicurie sources of a long-lived beta-emitting radioisotope are difficult to prepare. Cerium-144, a fission product ideally suited for use as a beta source, is expected to be available in large quantities in the near future. Cesium-137, also a fission product, will be a strong rival of cobalt-60 as a gamma source as soon as encapsulation techniques have been solved.

The encapsulation of beta-emitting radioisotopes is complicated by the absorption of the beta rays by the walls of the capsule. The capsule must be strong to prevent the escape of any of the radioactive isotope and yet sufficiently thin to permit the beta particles to exit. A possible solution may be a "window" in the capsule of the order of several thousandths of an inch in thickness. Other possible methods of preparing beta sources are also being considered.

Problems involved in preparing multicurie sources of gamma-emitting radioisotopes have been to a large extent solved. Gamma sources containing thousands of curies of cobalt-60 are now being used routinely. As gamma rays are difficult to stop, thick-walled capsules can be used without sacrificing much of the gamma radiation. Sources containing hundreds and even thousands of curies of cobalt-60, already encapsulated and shielded, can be bought commercially from the Brookhaven National Laboratory. The complete unit is usually in the form of a cylinder of lead. Inside the lead shielding is a metallic tube with cobalt-60 inserted in its wall. The material to be irradiated is lowered into the center of this metallic tube. One



The approximate thickness of shield material required to reduce the radiation level at the surface of a shield to the maximum permissible radiation level per worker (300 milliroentgens per week, 6.25 milliroentgens per hour).

hundred curies of cobalt-60 arranged in this manner has a radiation intensity in the chamber greater than 100,000 roentgens per hour. A unit containing 100 curies costs one to two thousand dollars.

A cobalt-60 installation of the "swimming pool" type is being installed by some users. Equipment required for an experiment as well as material to be irradiated can be placed inside a large water-tight tank. This tank is lowered into the pool to a depth of several feet depending on the number of curies of cobalt-60 used (for 1000 curies approximately 10 feet). The cobalt-60 which is permanently stored in the pool is brought into position and the irradiation carried out. The water in the pool serves as a cheap radiation shield.

What to Expect

The next few years should see many new applications of large sources of radioisotopes. Sterilization and cold pasteurization of foods and medicines now being conducted on laboratory and pilot-plant scale will graduate into plant production as soon as techniques for the encapsulation of kilo- and million-curies of beta-emitting fission products have been perfected. Radioactive radiation will be substituted for ultraviolet radiation in the production of many chemicals. Luminescent paints stimulated by beta radiation will find many civilian as well as military uses as the paint will carry its own power supply incorporated directly into its molecules. Studies concerning the combustion of fuels subjected to ionizing radiation may provide us with more efficient combustion engines, thus reducing fuel consumption. The instrument industry is finding new ways to use radiation in such instruments as the height gage, the thickness gage, and others. This should result in products of a more uniform quality, as well as cheaper production methods.

The fear of radiation, which once hindered the use of radioisotopes, is disappearing as management realizes that with intelligent care large amounts of radioisotopes can be used safely.

Sources of cobalt-60 as high as 10,000 curies have been reported. The radiochemist is now thinking in terms of the preparation of million-curie sources of radiation.

With the availability of large quantities of radioisotopes for industrial use, many companies are looking for ways to put radioisotopes profitably to work. Even companies that can see no immediate need for this tool are sending employees to Oak Ridge, to attend courses in nuclear chemistry offered by the Oak Ridge Institute of Nuclear Studies.

Universities are offering courses in nuclear physics and radiation chemistry to engineering students. As these graduates become dispersed throughout industry, companies that now have little knowledge of the potentialities of radioisotopes will become aware of their uses. One can look forward to the day when large radiation sources will be just another useful source of energy in the industrial plant.

Our wealth, our standard of living, our security and our future depend upon a complex combination of things: a free, restless, skilled, vigorous people, their natural resources, and a stimulating economic climate of freedom of enterprise. Without this freedom to stimulate the flow from basic science to applied science, from know-why to know-how, we can stand in danger of losing the future. But neither know-why, know-how, or freedom of enterprise stand alone. We must support them all. Tooling physically is in many ways similar to constructing a Maginot Line. It will secure us from frontal attack. It is certainly not sufficient. We must tool mentally as well, lest we become vulnerable from behind, from the direction of pure science. Finally, it is part of our responsibility, if we believe these things, to see that the public in general is informed in order that it may act intelligently in any crisis that may lie ahead.

—A. M. Zarem, Stanford Research Institute

Tin in the American Economy

by Bruce W. Gonser

Dr. Gonser, an assistant director at Battelle, has supervised research in nonferrous metallurgy there since he became associated with the Institute in 1934. He has written voluminously for periodicals in the field and is the author of numerous chapters in technical volumes. The author also holds important patents. As a member of the major metallurgical societies, he is often called upon to hold key offices and to serve on major committees.

Finding adequate sources of raw materials has been a challenge to United States industry since the begining of World War II. Defense needs have put a serious strain upon our metal resources. Steps taken to relieve this strain have included stringent conservation measures, stepping up imports wherever possible, and expanding our research related to raw materials. These difficulties have helped to open up a bright future for such metals as aluminum, magnesium, titanium, and molybdenum and for synthetics, such as plastics.

In view of the reshuffling in raw materials usage, one might wonder about the prospects for an old stand-by like tin. The tin can followed the American soldier around the globe during the last war. It occupies considerable space in everybody's kitchen cabinet. Use of tin in bronze, in solders, and in bearing alloys is old and well established.

Importance in Our Economy

Almost complete dependence on foreign sources of supply for tin can be a weak spot in our economy during periods of war and defense mobilization. The trend in the United States, therefore, is to attempt to make the country less dependent on tin. This is being done through the development of more efficient methods of using a given quantity of tin and through the use of alternative materials.

Tin, however, is not a "dying" metal. Because of its excellent properties, its uses are varied and deeply ingrained in our economy. Many of the alternative materials that have been developed for use in times of drastic tin scarcity are more expensive or less satisfactory than tin. They can serve, and they make us less dependent on tin, but as long as an abundance of tin is available, it may be uneconomical to use some of the substitute materials or procedures. Thus, with tin, we are approaching that desirable state of affairs where we can use tin effectively for many useful purposes when it is available, but we can get along with very little when the metal is in short supply. Under continuing peacetime conditions, the volume of consumption of tin will continue even if there are some cost rises brought on by scarcity or higher costs of extraction. Moreover, under normal conditions, there should be a modest growth in the over-all use of the metal during the next twenty-five years.

Alternative container materials and more efficient methods of using tin may reduce tin needs for can making, its major use, by at last one-third of present requirements. Tin needs for some other uses, such as collapsible tubes and foil, have become comparatively small.

To offset this trend there are the dozens of other established uses for tin. Furthermore, research is seeking and finding new applications for the metal. Examples are increased usage in electrotinning and in tin-alloy coatings.

Tin-ore reserves appear to be adequate for at least twenty-five years' production at the present or a moderately increased rate. Chances for adding to these reserves are fair, through continued exploration and improved technology of mining and refining.

Tinplating Developments

During the past decade, the making of tin plate, which accounts for about one-half of the tin consumption in the United States, has been undergoing a vast change. There has always been a minimum practical thickness for "hot-dip" coatings, the time-honored method of making tin plate. A pre-World War II development known as "electrotinning" makes it possible to produce tin plate of almost any thickness. This has greatly reduced the amount of tin necessary to do a given job. In 1951, the can industry used 41,000 long tons of tin to make 25 billion cans, but only

31,500 tons in 1952 to make 34 billion cans. In other words, the industry has cut the amount of tin per can by nearly 45 per cent.

About two-thirds of all tin plate made in the United States in 1952 was electrolytic tin plate. This trend toward replacing the old "hot-dip method" is continuing, but at a reduced rate. Although the tendency is strong to convert entirely to electrolytic tin, it may take up to 25 years before this objective is accomplished. A small amount of hot-dipped plate will probably continue to be made for a few heavy-coating applications.

Many can ends are now made from coated, untinned black plate. Some can bodies, furthermore, are being produced from the same material. This is coated with can-lining materials. Because they cost more, however, it appears that coated black plate cans will be used only in emergencies when the necessity to save tin becomes more critical.

Experimentation on aluminum-coated steel for can making has shown some promise. It may eventually become a strong economic competitor of tin plate. Aluminum-coated steel cans may be suitable for use for about half of the Nation's can requirements.

If necessary, the amount of tin solder could be curtailed to possibly a third of its present total volume. The average content of tin in solder used for can making has already been reduced from about 40 per cent to less than 5 per cent. Much tin-free solder, furthermore, is currently in use. It will not be feasible economically, however, to reduce the total volume of solder used by more than a small per cent in the foreseeable future. This is largely because of the demands of soldered electrical connections and other miscellaneous applications where soft, tin-lead solders are the easiest to apply.

New uses for tin are being developed to replace a part of the expected losses in old applications. Most promising of the new uses are in new alloys and in the coating of various products by electrodeposition with tin and tin alloys. Coating electrolytically with tin alone is scarcely new, but some improvements in the process have made control easier and results more dependable.

Uncertainty of Supply

World production of tin has substantially exceeded consumption in each of the last five years. The excess production has gone largely into emergency stockpiling. In 1951 the world production of tin in concentrates was 167,500 long tons as compared to a world consumption of 137,000 long tons; the difference was fully as great in 1952. Stockpiling needs eventually should be satisfied and an abundance of tin made available for every use.

Tin must be imported over vulnerable lines of transportation from southeastern Asia, Africa, Bolivia, and from European smelters. Greater control over this problem has already been secured through the development of alternative materials and more efficient methods of using a given quantity of tin. The trend toward alternative materials will be accelerated whenever overseas supply lines are jeopardized, or when alternatives to present tin usage are proved technically feasible and more economically worth while. In spite of all this, however, tin is such a useful metal that industry will continue to consume it at is present volume for a long time to come.

A . . . cause for optimism (in the chemical industry) is the large number of technically trained chemists and chemical engineers who now constitute a major part of the sales forces of most chemical companies. These men have been trained to think in terms of new chemicals and new uses for old chemicals, and are valuable allies of the research chemist and the market researcher. These men, mostly trained at the laboratory bench or in plant production, talk the same language as the research chemist and already have demonstrated conclusively the will and ability to suggest new approaches to research which have culminated in volume tonnages of new chemicals.

—Walter J. Murphy, Editor, *Chemical and Engineering News*

Notes From Battelle

METALS IN 1952

The metals industry is starting off the year 1953 in a relatively favorable position. During 1952, "Increased production, use of substitutes, and improved stockpile situations all contributed to a better balance between supply and demand and to the lifting of controls and restrictions on the less-critical metals." This is the conclusion of Dr. Ivor E. Campbell of Battelle in his report in *Chemical and Engineering News.*

He points out that the production of steel, aluminum, and copper was at a high level in 1952. At the research and development level, titanium was the big news with progress in both production and fabrication. However, activities in the refractory-metal field also became highly important because of the increasing need for high-temperature materials.

Among the important developments reported in Campbell's review are the following:

- The announcement by the Bureau of Mines of the preparation of ductile sheet chromium and of ductile alloys containing up to 40 per cent chromium on a laboratory scale.
- The use of sacrificial magnesium anodes in marine applications and the improvement in methods of protecting magnesium with the claim that it can be made as serviceable as properly protected steel or aluminum under average conditions.
- The consolidation of special aluminum powders containing controlled amounts of oxides, by powder-metallurgy techniques, followed by extrusion as rod and bar stock. This material has high-temperature properties markedly superior to the best aluminum alloys previously available.
- The continuous casting of stainless and alloy steels was developed to the point where it is expected to become a commercial reality in 1953.
- Hot extrusion of cast iron into hollow sections was successfully achieved, showing that a brittle non-malleable metal can be extruded.

DIVERSIFICATION IN PLASTICS

"Diversification might be said to have been the keynote in plastics in 1952," in the opinion of Dr. E. E. McSweeney of Battelle as presented in his review of plastics that appeared in the January 5 issue of *Chemical and Engineering News.* McSweeney points out that many chemical companies are viewing the plastics field as an increasingly important raw materials market and an excellent field for diversification; plastics manufactureres are also seeking markets in practically every field of technology.

One of the new uses for existing plastics disclosed last year was their application as soil conditioners. The year 1952 also saw increasing interest in the use of "old" plastics for such products as car bodies, fiberglass tanks, hose, piping, refrigerator-door liners, and battery cases.

During 1952, considerable interest was aroused by: the possible use of vinyltoluene in place of styrene in some applications; the conversion of xylenes to the three isomeric phthalic acids; the introduction of improved polyvinyl chloridex polymers and copolymers; and improved styrene copolymers and "alloys" of greater toughness.

EFFECTIVE LIGHT FOR ALBUMIN FILMS

The United States Army has as real an interest in the graphic arts as they do in many other fields. Among other uses, the Army requires mobile lithographic printing units for serving forces in the field. For this reason, Battelle was recently asked to provide a basis for selecting the most efficient light source for irradiating dichromated albumin films on lithographic plates.

When exposed to light, a dichromated albumin film tans or hardens. Thus the portion of the film exposed to the light passing through a negative, hardens and sticks to the metal when the plate is developed. Since the hardened film is receptive to oily inks, while the exposed metal of the plate rejects oil, the processed plate may be used for printing in the lithographic process.

Selecting the most efficient light source for dichromated albumin calls for a knowledge of the wavelengths of light to which the film reacts. In the investigation, the film was exposed to isolated spectral ranges of light from a carbon arc lamp. The response of the dichromated albumin to the various ranges was measured by the unique method of measuring the color change in the films.

The investigations covered light wavelengths from 700 to 200 millimicrons. The film was found to be most sensitive to wavelengths shorter than 320 millimicrons —the ultraviolet region—with no sensitivity above 600 millimicrons. Light in the shorter wavelengths was found to harden the film through to the metal more

efficiently. This hardening gives greater assurance that the pattern will not be washed off during the development of the plate.

MOLYBDENUM FOR HIGH TEMPERATURES

Molybdenum and its alloys appear to be most promising for development of the next step up the temperature scale. For this reason, there is considerable interest in the elevated-temperature properties of the metal and of its base alloys. A report on "A Metallurgical Study of Molybdenum" for the Office of Naval Research was made late in November at Cleveland by Howard Cross. The occasion was the ASM Conference on Refractory-Type Materials for High Temperature Application.

Research at Battelle was directed by Cross to determine the high-temperature properties of pure molybdenum and of several of its alloys. Stress-rupture tests were made at 1600, 1900, and 2000 F. Because of molybdenum's poor resistance to oxidation, all tests were made in a vacuum.

Molybdenum shows considerable variation in properties, depending on how it is fabricated and the conditions under which it is tested. At 1600 F, 100-hour rupture tests range from 15,000 to 30,000 psi. At 1800 F, the 100-hour rupture strengths for pure molybdenum ranged from about 10,000 to 18,000 psi, and at 2000 F, from about 5000 to 10,000 psi. Ductility, as indicated by elongation at rupture, was good.

The 100-hour rupture strengths for superalloys S-816 and HS-31 are 14,000 and 21,000 psi, respectively, at 1600 F, and at 1800 F are 10,500 and 11,300 psi, respectively.

Research indicates that, as more is learned about alloying and fabrication, still higher strengths may be available. However, long-time strength properties at high temperatures depend upon finding the means of protecting molybdenum-base materials from oxidation.

TITANIUM CASTING

Uncontaminated titanium is a ductile, corrosion-resistant metal with high strength-to-weight ratio. However, titanium is so chemically active when molten that it reacts with or dissolves most known refractory materials. Even small amounts of oxygen, nitrogen, or carbon will cause the metal to become very hard and brittle, Therefore, the development of processes for casting titanium presents many difficult problems.

Metallurgists at both the Frankford Arsenal and Battelle are attacking these problems on two fronts. They are trying to develop (1) a method for making high-purity titanium melts large enough to be cast into molds, and (2) mold materials that will not react with or contaminate the castings.

A skull-melting arc furnace for melting high-purity titanium has been built at Battelle for evaluation of promising mold materials. Preliminary screenings of these materials are being carried out in an assembly which utilizes a graphite-lined, induction-melting furnace which operates in a sealed dome.

Investigations thus far indicate that titanium castings up to a half-inch in cross section can be cast with good surface finish and accurate reproduction of detail in graphite-washed zirconia or graphite-washed alumina shell molds. In castings with more than one-half inch cross section, there may be difficulty with pinholing and mold reaction. On the other hand, acceptable castings, possibly up to two inches in cross section, can be cast in zirconia molds bonded with zirconium oxychloride. Because of the limited use and costliness of materials developed in these investigations, more work must be done to develop better and less expensive mold materials.

Most of the defects in the test molds occurred at the re-entrant angles where there was a change in the section size. With improved casting design, it may be possible to eliminate pinholes that have appeared in many of the castings made so far.

NONDESTRUCTIVE TESTING RESEARCH

Samuel A. Wenk has been named to supervise nondestructive testing research at Battelle. He has been closely associated with the work for the past three years, a period marked by the growing importance of the field.

Samuel A. Wenk

Before joining Battelle in 1948, Wenk was chief Metallurgist for Bowser, Inc. During the war years, he served as Chief of Inspection for the Pittsburgh Ordnance District and Chief Production Engineer for Heavy Caliber Ammunition in the Office of Chief of Ordnance. A graduate of the Virginia Polytechnic Institute, Wenk has his bachelor of science degree in metallurgical engineering. He is a member of Committee E-7 on nondestructive testing of the American Society for Testing Materials.

RECENT PAPERS AND ARTICLES BY THE RESEARCH STAFF*

Metal Industries (Review of 1952). I. E. Campbell. *Chemical and Engineering News*, January 5, 1953.

Stress in Large Diameter Gas Transmission Pipe. J. W. Lodge and G. K. Manning. *Pipeline News*, January, 1953.

Determination of Hydrogen in Magnesium, Lithium, and Magnesium-Lithium Alloys. M. W. Mallett, A. F. Gerds, and C. B. Griffith. *Analytical Chemistry*, January, 1953.

Analogous Systems in Engineering Design. R. C. McMaster, R. L. Merrill, and B. H. List. *Product Engineering*, January, 1953.

Plastics (Review of 1952). E. E. McSweeney. *Chemical and Engineering News*, January 5, 1953.

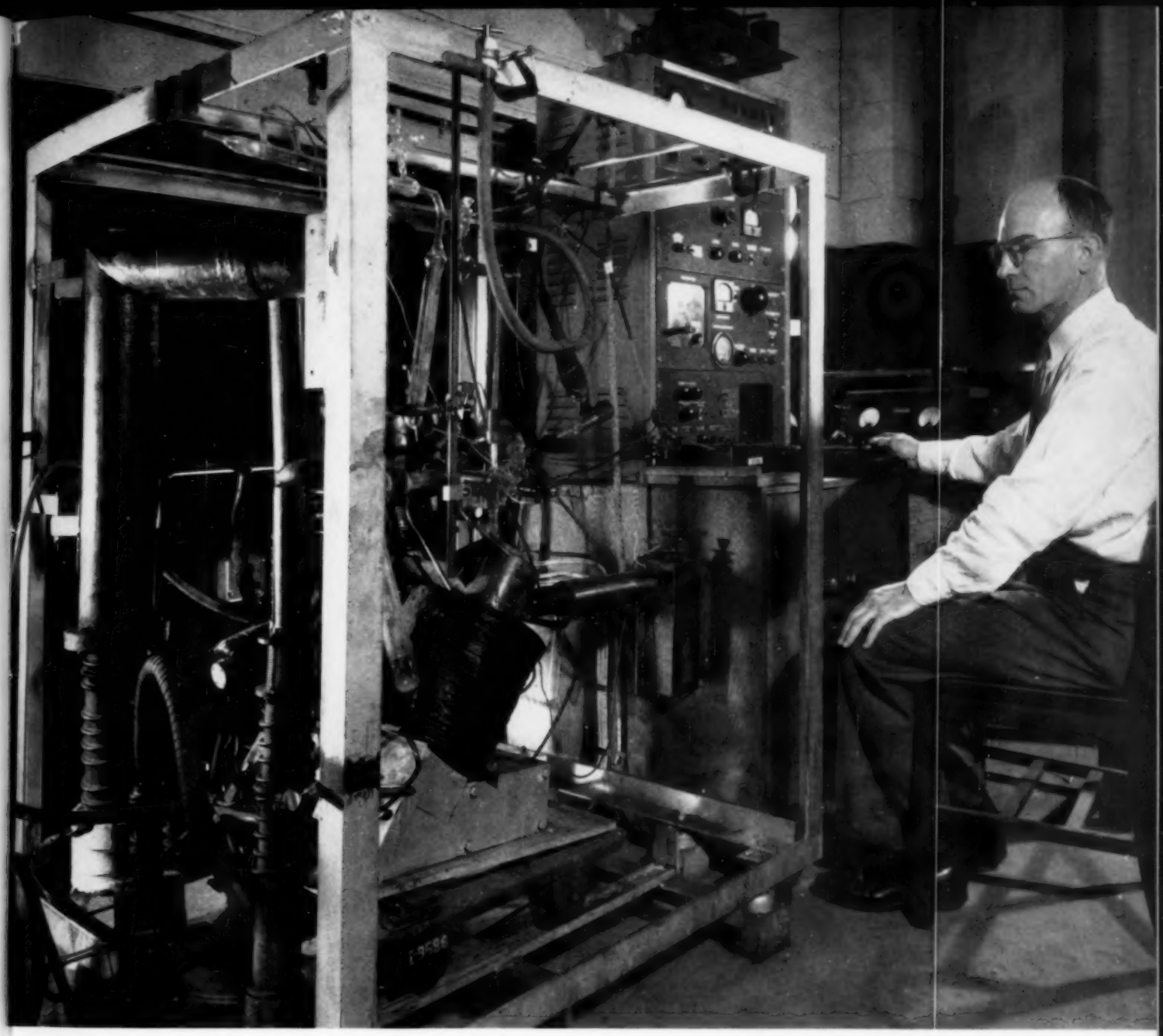
New Developments in Package Checkweighing. R. L. Merrill. *Packaging Review* (Manchester, England), December, 1952.

Metals for Defense in the Free World. Clyde Williams. Proceedings of the First World Metallurgical Congress, 1952, (American Society for Metals).

*In most cases, reprints will be available from the Battelle Publications Office upon request.

A Word About Battelle Technical Review Abstracts

The abstracts that appear in the following pages are prepared from approximately 950 American and foreign technical journals, as well as from books and other literature received in the Battelle Library. Prepared by a professional staff trained in various technological fields, the abstracts are selected for their usefulness to the Battelle research staff. They are now being made available to technologists and scientists in industry and research in all parts of the world, through the pages of the *Battelle Technical Review*.



SUPERSENSITIVE MASS SPECTROMETER

This Battelle-built mass spectrometer is used in studies of diffusion combustion to analyze minute amounts of gases continously. The sample is taken by means of an extremely fine probe, so that the rate of withdrawal does not appreciably change either the concentration or the lines of flow of the diffusing gases.

BATTELLE INSTITUTE was founded by the will of Gordon Battelle as a memorial to the Battelle family. The Battelles were among the first settlers of Ohio and were prominent in the development of the state's iron and steel industry.

Gordon Battelle, last of the family line, was impressed with the benefits to be derived from industrial research and left his estate for the building and endowment of an Institute "for the purpose of education . . . the encouragement of research . . . and the making of discoveries and inventions for industry." The Institute began operations in 1929.

As established Battelle provides, on a not-for-profit basis, the physical plant, equipment, and personnel for conducting research. The great bulk of it is applied research conducted for industry and government.

In keeping with its educational function, the Institute also conducts fundamental or basic research. The results of much of this research are published for the general encouragement of science and industry, and to benefit the public welfare.

Fields of research at Battelle include agriculture and practically all the industrial and engineering sciences.

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